

Report of the Land Disposal of Sludge Subcommittee  
Projects Conducted 1971 - 1978  
Research Report No. 70

**Research Program for the Abatement of Municipal Pollution  
under Provisions of the Canada-Ontario Agreement  
on Great Lakes Water Quality**

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## CANADA-ONTARIO AGREEMENT

### RESEARCH REPORTS

These RESEARCH REPORTS describe the results of investigations funded under the Research Program for the Abatement of Municipal Pollution within the provisions of the Canada-Ontario Agreement on Great Lakes Water Quality. They provide a central source of information on the studies being carried out in this program through in-house projects by both Fisheries and Environment Canada, and the Ontario Ministry of the Environment, and contracts with municipalities, research institutions and industrial organizations.

Inquiries pertaining to the Canada-Ontario Agreement RESEARCH PROGRAM should be directed to -

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Toronto, Ontario M4V 1P5

BBRT

REPORT OF THE LAND DISPOSAL OF SLUDGE SUBCOMMITTEE  
PROJECTS CONDUCTED 1971 - 1978

RESEARCH PROGRAM FOR THE ABATEMENT  
OF MUNICIPAL POLLUTION WITHIN THE  
PROVISIONS OF THE CANADA-ONTARIO  
AGREEMENT ON GREAT LAKES WATER QUALITY

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This document may be obtained from -

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CANADA-ONTARIO AGREEMENT  
RESEARCH PROGRAM FOR THE ABATEMENT OF MUNICIPAL POLLUTION

The Government of Canada and the Government of the Province of Ontario on August 13, 1971 signed an Agreement (The Canada-Ontario Agreement on Great Lakes Water Quality) to ensure that the water quality of the Great Lakes is restored and protected.

The purpose of this Agreement was to permit Canada and Ontario to carry out their obligations under the Canada-United States Agreement on Great Lakes Water Quality. One of the major programs accelerated under the Agreement was a plan to control phosphorus discharges from more than 200 existing municipal wastewater treatment plants in Ontario serving some 4.7 million people.

An additional important financial provision of the Agreement was for a research program directed towards reducing the cost of waste treatment programs as well as ensuring that the latest technological advances are incorporated into such programs. Funding for this activity has been shared equally by the Federal and Provincial governments to a total of \$7.0 million over the seven year term of the Agreement. Of the funds available over the term of the Agreement, approximately 50% have been used for treatability studies and research related to phosphorus removal, the balance being for research activities designed to improve sewage treatment processes and decrease their cost. A considerable amount of research was conducted in-house by the Ontario Ministry of the Environment and by the Canadian Department of Fisheries and Environment. However, external contract studies were a significant part of the total program and such arrangements have been made with a number of industrial organizations, consulting engineering firms, research foundations and universities.

The broad areas of research activity were as follows:

1. Chemical treatment using various existing municipal processes.
2. Removal of phosphorus from sewage at municipal sewage treatment plants.
3. Chemical-physical and other advanced wastewater treatment concepts.

4. The treatment, handling and ultimate disposal of sewage sludge.
5. The upgrading of existing municipal sewage treatment plants.
6. Studies on the reduction of discharges of persistent organic contaminants and toxic substances from municipal treatment plants.
7. The abatement of pollution from storm and combined sewers and urban drainage.

In order to administrate research programs in these activity areas four subcommittees were appointed.

The report which follows is an account of the work of one of the Subcommittees (Land Disposal of Sludge Subcommittee) between 1971 and 1978. Its activity related chiefly to the handling and ultimate disposal of sewage sludge.

## LAND DISPOSAL OF SLUDGE SUBCOMMITTEE

A significant concern that has been identified is the disposal of municipal sludges produced from the chemical treatment of sewage for phosphorus removal. In addition, the desire to utilize this nutrient-rich material on agricultural lands, and the awareness of the possible presence of significant concentrations of toxic metals and other potentially harmful substances in sludges, has resulted in a need to conduct intensive investigation in the area of sludge disposal. In this regard the Subcommittee was requested to develop a strategy for research activities, to commend and to oversee projects relating to sludge disposal as well as to provide advice on questions referred to it.

### Terms of Reference of the Subcommittee

1. To provide advice and direction in the development of a research strategy in the area of application of sewage sludge to land.
2. To liaise with groups concerned with environmental quality aspects of sludge disposal on land.
3. To review research proposals and assess their implications.
4. To provide general advice in these areas.

### Research Strategy of the Subcommittee

Through support of research funding provided under the Canada-Ontario Agreement, considerable research work into land disposal of sludges has been carried out in-house and through contracts.

In Ontario, a majority of the small to medium-sized pollution control plants dispose of processed sludge through application onto agricultural land. This is about 34% of all sludge produced. While sludges have been disposed of on land for many years, concerns have mainly been associated with odours. These, as well as aesthetic concerns, have resulted in political objections and subsequent local restrictions. It is only in recent years that questions have arisen concerning the potential environmental problems associated with this method of disposal. The introduction of chemical sludges from phosphorus removal facilities has raised further questions concerning this practice.

The application of sewage sludges onto agricultural lands under the proper conditions is not only economical but can result in fertilization and improve soil properties for greater uses. The widely accepted concept of recycling is also being effected by this practice. Through support of research funding provided under the Canada-Ontario Agreement, considerable research work into land disposal of sludges has been carried out. Canada-Ontario Agreement supported research has provided a significant data base to enable the Ontario Ministry of the Environment and the Ministry of Agriculture and Food to develop guidelines for the utilization of processed sewage sludges on some agricultural lands. The guidelines will be kept under continual review and will be updated as investigations continue.

#### Problems of Land Disposal of Sludges

1. Current guidelines for sludge disposal in Ontario were derived from experience with commercial fertilizers and farm animal manures and a limited amount of knowledge concerning sewage sludge composition, nutrient availability, etc. Studies with sewage sludges were required to fully understand and determine the availability, transport and ultimate fate of nutrients and heavy metals in soils, vegetation and ground and surface waters.
2. The level of heavy metals in sludges is of concern because of potential problems associated with:
  - (a) build-up in soil,
  - (b) uptake by plants,
  - (c) effect on plant growth,
  - (d) pollution of surface water due to runoff,
  - (e) pollution of groundwater,
  - (f) leaching after long-term build-up in soil,
  - (g) animal and human health related to ingestion of metal contaminated crops.
3. Research was needed to determine what is required during digestion to reduce odour and pathogens.
4. Biological aspects, such as viruses, parasites and worms in soil and crops to which sewage sludge has been added, were of concern.

5. Sewage sludges contain a large fraction of organic compounds heretofore not defined. This may pose problems depending on the levels present.

In view of the emphasis being placed on recycling and energy conservation, increased pressures will be applied to use agricultural lands for the disposal of sewage sludge, which is recognized as a re-useable resource. Past practices have not taken into consideration all of the environmental factors involved. In recognition of these problems, considerable research has been undertaken to determine not only the effect of such practices but also the limits of acceptable practices.

#### Technology Transfer Activities

In order to ensure that all persons concerned with problems associated with land disposal of sludges were kept informed of activities in this area, the Subcommittee organized a Sludge Handling and Disposal Seminar in 1974. In addition, many of the researchers who received funding for their activities as part of this program were active participants at a Sludge Handling and Disposal Seminar held in Calgary, Alberta in 1977.

The work carried out under the purview of the Subcommittee has also resulted in papers being presented at conferences. These are listed in the summaries for the various projects as appropriate.

As part of the overall technology transfer activities associated with research under the Canada-Ontario Agreement, reports on all of the studies being supported are compiled. A number of reports have been prepared in support of this program to date, and others will be prepared once studies have been completed. The availability of the reports and their current status is listed in the project summaries and it should be noted that if copies of reports are required, these may be obtained from either the Ontario Ministry of the Environment (MOE) or from the Department of Fisheries and Environment (DFE), Environmental Protection Service.

#### Land Disposal of Sludge Subcommittee Membership

Co-Chairmen:

S.A. Black        -    Ontario Ministry of the Environment

J.R. McMurray\* - Ontario Ministry of the Environment  
K. Shikaze - Fisheries and Environment Canada

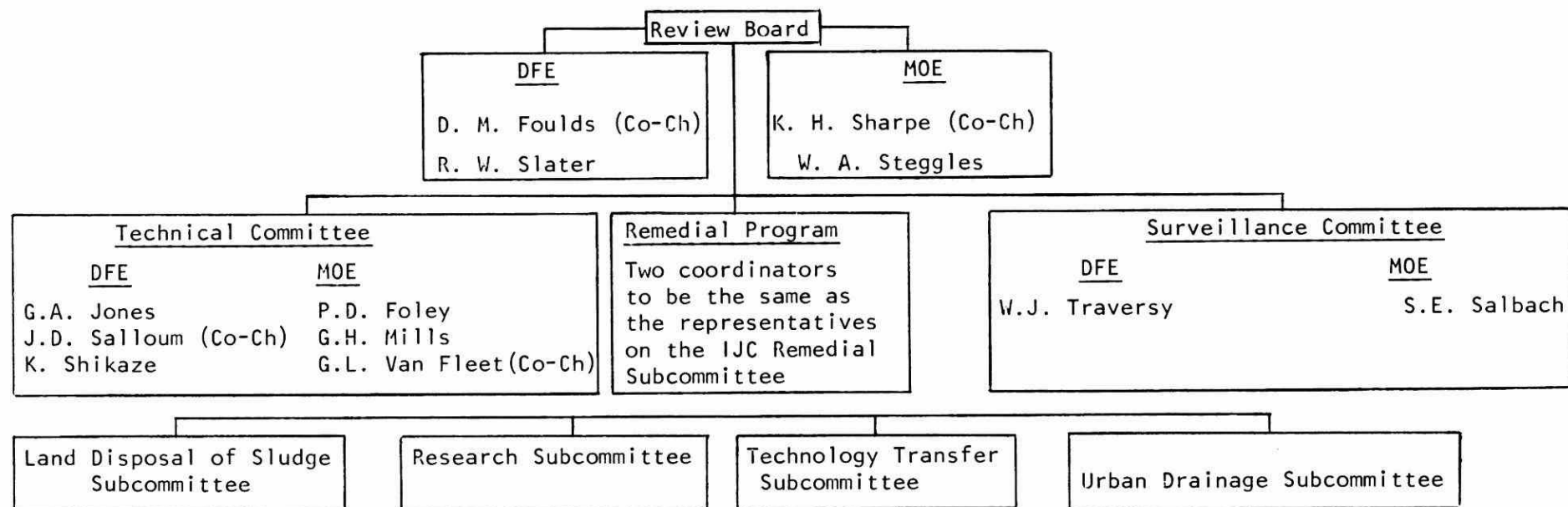
Members:

H.T. Chan - Ontario Ministry of the Environment  
R. Frank - Ontario Ministry of Agriculture and Food  
F.R. Hore - Agriculture Canada  
B.P. LeClair\* - Fisheries and Environment Canada  
W.E. Lowe - Fisheries and Environment Canada  
J.W. Schmidt\* - Fisheries and Environment Canada  
N.W. Schmidtke - Fisheries and Environment Canada  
G.M. Wood - Ontario Ministry of the Environment  
P. DeAngelis - Ontario Ministry of the Environment (Alternate)

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\* Past Members

# CANADA-ONTARIO AGREEMENT ORGANIZATION CHART - 1977



## Members

### Federal

F.R. Hore  
W.E. Lowe  
N.W. Schmidtke  
K. Shikaze (Co-Ch)

### Provincial

S.A. Black (Co-Ch)  
H.T. Chan  
R. Frank  
G.M. Wood (P. De Angelis, Alternate)

Originally, the Canada-Ontario Agreement was planned to continue for five years terminating December 31, 1975. The Agreement has been renegotiated to cover the whole of the Great Lakes system with an extended time frame. Both surveillance and research are identified in the new Agreement.

Project Funding FY 72/73 to FY 77/78

| Project No.                                                            | Project Title<br>Description of Project                                                                | Project Location                           | Units = \$000 |       |       |       |       |        | Total Expenses and Budget |
|------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|--------------------------------------------|---------------|-------|-------|-------|-------|--------|---------------------------|
|                                                                        |                                                                                                        |                                            | 72/73         | 73/74 | 74/75 | 75/76 | 76/77 | 77/78* |                           |
| 72-5-1                                                                 | Examination of Sewage and Sewage Sludge for Enteroviruses                                              | Ontario Ministry of Health                 | 4.2           | 11.8  | 14.2  | 10.0  |       |        | 40.2                      |
| 72-5-3                                                                 | Heavy Metals in Agricultural Lands Receiving Chemical Sewage Sludges                                   | University of Toronto                      | 15.0          | 10.0  | 13.8  | 7.5   |       |        | 46.3                      |
| 72-5-17                                                                | Land Disposal of Sewage Sludge                                                                         | University of Guelph                       | 47.7          | 121.4 | 143.1 | 178.5 | 105.4 | 93.0   | 689.1                     |
| 72-3-6                                                                 | Chemical Sewage Sludge Disposal on Land - Lysimeters                                                   | Environmental Protection Service DFE       | 37.2          | 33.0  | 31.5  | 40.6  | 22.5  | 35.0   | 199.8                     |
| 72-5-18                                                                | Sewage Sludge Interactions with Soil Materials                                                         | Soil Research Institute Agriculture Canada | 4.2           | 8.1   | 23.4  | 13.1  |       |        | 48.8                      |
| 73-3-11                                                                | Biochemical Characteristics of Digested Chemical Sewage Sludges                                        | Environmental Protection Service DFE       |               | 19.3  | 7.9   |       |       |        | 27.2                      |
| 73-5-9                                                                 | Land Application of Sewage Sludge under Adverse Conditions                                             | Regional Municipality of Niagara           |               | 3.3   | 2.0   |       |       |        | 5.3                       |
| 74-3-16                                                                | Development of an Efficient Sampling Strategy to Characterize Digested Sludges                         | Environmental Protection Service DFE       |               |       | 17.1  | 18.0  |       |        | 35.1                      |
| 74-1-41                                                                | Investigation of Parasites in Sewage Sludge                                                            | Ministry of the Environment                |               |       | 1.9   | 13.6  | 16.7  | 15.0   | 47.2                      |
| 74-3-19                                                                | Survey of Ontario Sludge Disposal Practices                                                            | Environmental Protection Service DFE       |               |       | 2.6   | 13.3  |       |        | 15.9                      |
| 76-3-26                                                                | Determination of Existing Levels of PCBs and Heavy Metals at Selected Sludge Disposal Sites in Ontario | Environmental Protection Service DFE       |               |       |       |       | 16.6  |        | 16.6                      |
| TOTAL USED BY SUBCOMMITTEE SINCE START OF THE CANADA-ONTARIO AGREEMENT |                                                                                                        |                                            | 108.3         | 206.9 | 257.5 | 294.6 | 161.2 | 143.0  | 1171.5                    |

\*FY 77/78 Budget Allotments

## PROJECT SUMMARY

Project Title : Examination of Sewage and Sewage Sludge for Enteroviruses

Project Leader : T.P. Subrahmanyam

Scientific Liaison Officer: Ann H. Vajdic

Project Number : 72-5-1

Contractor : Ontario Ministry of Health,  
Laboratory Services Branch

Contract Time : 1972-1976

Project Status : Completed

Status of Reports : Reports are published in the Canada-Ontario Agreement Research Report Series.  
Volume I is Report No. 27  
Volume II is Report No. 52

### Description and summary

Virus isolations were attempted from various samples of sewage sludge, both raw and digested, raw sewage and runoff water from sludged agricultural plots; laboratory experiments were carried out to determine the sensitivity of the methods, and the techniques used are fully described. All isolates were identified and typed as far as possible using specific antisera pools; genetic marker tests were carried out on all polio isolates. Some work to determine the survival times of polio virus in sludge stored at 4°C and 25°C was completed.

### Results and conclusions

Nearly 1000 specimens were tested, and 40% of the raw sewage samples were positive in 1973, with subsequent recoveries being somewhat lower (25%) reflecting the low isolation rates.

The study was carried out during years of low enterovirus prevalence but it was guardedly concluded that spreading digested sludge on agricultural land poses only a low level virus hazard.

Summary of Research Report No. 27, Volume I

Project 72-5-1: EXAMINATION OF SEWAGE AND SEWAGE SLUDGE FOR ENTEROVIRUSES  
- T.P. Subrahmanyam, Ontario Ministry of Health

A promising and practical method for taking advantage of the nutrient qualities of sewage sludge is to spread it on agricultural or grassland in rural areas. This method, however, carries an inherent risk that the environment may be polluted further with harmful agents such as viruses and heavy metals. This report deals with the first phase of a virus monitoring program being carried out in the Enterovirus Laboratory of the Ontario Ministry of Health, Laboratory Services Branch, in connection with the plans to spread urban sewage sludge on rural land in Ontario.

The results of this program include virus surveillance studies on five Ontario plants which employ different phosphate removal techniques, as well as related laboratory studies.

Gauze pad collections of sewage samples or sludge samples, collected in 100 ml volumes soon after mixing tank contents, were transported without delay to the laboratory. The specimens were extracted with alkaline Earle's balanced salt solution (pH 0.5) and the extract decontaminated by chloroform treatment. The aqueous layer, freed of residual chloroform, was tested for viruses in primary and continuous cultures of monkey kidney and human diploid fetal lung (WI-38) cells at least three times and the presence of virus demonstrated by cytopathic effects and electron microscopy, as well as haemadsorption and interference testing. Any isolate was identified with pools of specific antisera to enteroviruses. In the case of poliovirus isolates, genetic marker and antigenic differentiation tests to distinguish between vaccine and virulent strains are in progress.

During April, 1973 - December, 1974, a total of 900 specimens including 438 sewage specimens, 398 raw and digested sludge specimens and 64 specimens of water were investigated. Of the 444 specimens tested in 1973, 40% of the sewage specimens (48/124) contained viruses, although the collection period included several cold months during which enteroviruses were not detected in the community. Virus isolation rates

in 1974 were lower, reflecting the generally lower isolation rates from clinical cases as well. Viruses from sewage included several poliovirus isolates. Preliminary results indicated that at least one strain was definitely not related to vaccines, and that perhaps a few others were of intermediate character, indicating that they too could be of non-vaccine origin. All the non-polio enteroviruses found in this study are well known human pathogens and, therefore, it is important to ensure that they are inactivated before sludge is spread on soil.

The amount and nature of the sanitary sewage produced by each community is influenced by a number of factors, including population density, standard of living and level of industrialization. Adequate sewage treatment is expensive but uncontrolled sewage disposal leads to undesirable consequences. While the serious environmental damage which might occur in the long run is of great concern, it should not be forgotten that residential sewage, rich in faecal material, often contains dangerous viruses and bacteria, such as the agents of hepatitis and typhoid.

It appears that raw domestic sewage has a protective effect on enteroviruses, perhaps because of the stabilizing influence of organic matter. In assessing the adequacy of sewage treatment, it is also important to remember that faecal matter and other solids present in sewage might contain adsorbed viruses for solids, viruses entering sewage are likely to be associated with faecal and other solids. They are, thus, likely to end up in the solid residue of sewage viz. sludge, from which they may be recoverable only under special conditions. If the sludge is rich in phosphates as a result of phosphate removal operations, the likelihood of viruses being present is even greater since nascent phosphate precipitates are excellent virus adsorbents.

It has been estimated that the daily accumulation of wet sludge in urban centres amounts to approximately ten litres per person, so that a city of 100,000 is faced with the disposal of a million litres of sludge every day. Safe disposal of such amounts of sludge should include efficient virus inactivation in view of the high probability of the presence of viruses. While some pollution control plants incinerate the sludge before disposal, there can be little doubt that it would be

preferable to recycle the nutrients in sludge by spreading it on agricultural land, if this can be done without damaging the land and endangering the health of people and livestock.

It can be said, guardedly, that spreading sludge probably poses only a low level health hazard. It is, however, unwise to make a definitive judgement in view of the low virus prevalence in the community and the absence of practical detection methods for hepatitis and gastroenteritis viruses.

#### Summary of Research Report No. 52, Volume II

Project 72-5-1: EXAMINATION OF SEWAGE AND SEWAGE SLUDGE FOR ENTEROVIRUSES  
- T.P. Subrahmanyam, Ontario Ministry of Health

The main objective of this study was to collect sewage sludge from selected pollution control plants in Ontario at regular intervals, and to test the specimens collected for the presence of pathogenic viruses by cell culture inoculation, electron microscopy and other related methods. A related objective was to determine whether faecally excreted viruses survive for prolonged periods in sludge destined for land application.

In studying methodology, the decontaminating efficacy of chloroform as a safe decontaminant in processing sewage extracts for enterovirus isolation was determined. In hundreds of tests using the chloroform treatment no difficulty was experienced due to bacterial contamination.

Studies were carried out on the efficiency of virus isolation procedures. It was possible to recover 100 to 10,000 TCID<sub>50</sub> of added virus from 10 ml without loss, showing that the extraction procedure is efficient. Results with sludge also appeared to be satisfactory if allowance is made for the initial virus loss. During the three years, 1973-1975, over 1300 specimens were examined. These included water, raw sewage, raw sludge and digested sludges. In the case of sludges, eleven percent of raw sludges and seven percent of digested sludges yielded viruses, but there were considerably more virus isolations from digested

sludges in 1975. Viruses were isolated from 21% of sewage influents examined (506). During the three years, 18 polioviruses belonging to all three types were isolated.

All the nonpolio enteroviruses identified so far have been found to belong to the coxsackie B group with one exception, which was a coxsackie A9 virus.

The report concludes guardedly that spreading sludge poses only a low-level health hazard. This is qualified by adding that virus prevalence in the community was low, and that practical detection methods are not available for the important agents responsible for hepatitis and gastroenteritis.

Surveillance should be continued and improvement of methodology of both sample collection and virus detection should receive priority. It is emphasized that any sewage-related material leaving the treatment plants should be treated adequately to ensure virological safety.

## PROJECT SUMMARY

Project Title : Heavy Metals in Agricultural Lands Receiving Chemical Sewage Sludges

Project Leader : J.C. Van Loon

Scientific Liaison Officer: S.A. Black

Project Number : 72-5-3

Contractor : University of Toronto  
Institute for Environmental Studies

Contract Time : 1972 - 1976

Project Status : Completed

Status of Reports : Reports are published in the Canada-Ontario Agreement Research Report Series.

|            |               |
|------------|---------------|
| Volume I   | Report No. 9  |
| Volume II  | Report No. 25 |
| Volume III | Report No. 30 |
| Volume IV  | Report No. 51 |

### Description and summary

This project was established to develop and refine analytical procedures for the determination of some heavy metals in sludges and to determine heavy metals in sludges at selected wastewater treatment plants in Ontario. In particular, analytical development work included the potential use of flameless atomic absorption; in depth investigation of the use of electro-chemical methods; improving existing methods for Hg, Ag, As, Se and Mo; and improving quality control.

The study also investigated the movement from disposal sites of heavy metals applied in sewage sludges to agricultural lands as related to soil properties, uptake by plant growth and contamination of surface and groundwaters.

### Results and conclusions

This study demonstrated that at the present time atomic absorption remains the most promising procedure for analysis of heavy metals. Anodic stripping and polarography require further development particularly for solids materials.

The development of a quartz "T" tube separator/atomizer appears to be a very important step in the study of metals in sludge particularly in determining plant uptake.

For atomic absorption, the use of the flame was determined to be still the atomizer of choice; furnaces can give serious background problems. In surface waters contaminated from runoff of sludged fields, metals are largely in the particulate fraction. Preliminary studies of groundwater indicate iron to be primarily in the particulate form more so than copper, nickel and zinc.

#### Summary of Research Report No. 9, Volume I

#### Project 72-5-3: HEAVY METALS IN AGRICULTURAL LANDS RECEIVING CHEMICAL SEWAGE SLUDGES - J.C. Van Loon, University of Toronto

The disposal of sewage treatment plant sludges poses a serious problem. Potentially, these materials could be used as fertilizers on agricultural lands. This would be a double benefit, acting as a disposal mechanism as well as a source of plant nutrients. On the other hand, a variety of reports have appeared urging caution in this regard for fear of contamination of the land by other matrix constituents. Among these are the potentially toxic heavy metals.

Despite a good deal of activity in this subject area, it is clear, from the references available to date, that very little data exist which reliably describe plant-metal interactions. Perhaps the most serious omission is that little attempt has been made in these papers to provide data on precision and accuracy of results.

In this project sludge characterization studies were conducted on samples obtained from North Toronto, Newmarket and Point Edward sewage treatment plants. Metal analyses were performed on Newmarket soils and vegetation on two farms which had received applications of sludge in 1971 and 1972. Metal analyses were also carried out on run-off water samples obtained in and around the sludge disposal area at the North Toronto sewage treatment plant.

The emphasis in this study was placed on the use of standard and control samples as tools for validating the data obtained. Because of the shortness of the investigation period, however, no attempt was made to use statistical testing to provide a means for arriving at conclusions. It would seem too early to justify anything but a few generalizations.

Appendix I of the report lists additional references not cited in the text which may be of use to interested readers.

#### Summary of Research Report No. 25, Volume II

Project 72-5-3: HEAVY METALS IN AGRICULTURAL LANDS RECEIVING CHEMICAL SEWAGE SLUDGES - J.C. Van Loon, University of Toronto

Heavy metal contamination studies of soils, vegetation, ground-water and surface water were carried out at the Burlington Skyway plant disposal farm and the North Toronto plant disposal area. A study of garden vegetable contamination due to the use of sludge for home gardening was also initiated.

Again, as in the previous year, emphasis was placed on using standard reference materials to give validity to the analytical data.

The following conclusions are made in this volume:

##### (a) Plant Uptake of Metals

There is little evidence of high heavy metal uptake by vegetation. An exception occurred in the case of mercury levels found in tomato fruit and possibly bean pods grown on sludged soil. In this instance, on a dry weight basis, the mercury levels were found to be 20 times higher or more than in the control samples. On a wet weight basis, the mercury levels in tomatoes would be up to 1 ppm.

Zinc and copper, in most cases, were elevated in vegetation grown on sludged land. Here, however, the increases were generally less than twice the control plant levels.

Work has been initiated to improve the lower limit of cadmium detection in these sample matrices. It will be important to continue methods development research related to cadmium.

All soils and sludges used above were alkaline in pH (a common situation in southern Ontario). Uptake from acidic soils is more probable and this possibility should be explored.

(b) Surface Contamination of Vegetation by Sludge

Perhaps the most serious potential problem comes from surface contamination of vegetation. Research showed that unless vegetation was scrupulously washed (i.e. rub surfaces with fingers and use a mild detergent) elevated metal levels for vegetation were recorded. It is well known that most people do not wash vegetation with detergent as indicated above. In the case of forage crops, sludge is commonly applied after sprouting and, hence, can easily remain on the plant surfaces to be ingested by farm or wild animals.

(c) Plant Age vs. Metal Content

In general, a decrease in metal content with increasing age of vegetation was noted.

On the whole, the North Toronto well results showed large variations in iron and zinc values and little variation in copper and nickel values within the period of study. Iron appeared to be most strongly affected by filtration, and copper and nickel least. Zinc, from time to time, showed increasing values with decreasing porosity of the filter medium.

Summary of Research Report No. 30, Volume III

Project 72-5-3: HEAVY METALS IN AGRICULTURAL LANDS RECEIVING CHEMICAL  
SEWAGE SLUDGES - J.C. Van Loon, University of Toronto

This report is divided into two subject areas:

- (A) Analytical Methods Development for Metals
- (B) Sludge Analysis for Metals

In category A, work was centered on atomic absorption and electrochemical (anodic stripping and polarographic) methods. Methods development work gives emphasis to "total" metal analysis because of a

lack of proven procedures for some important elements such as As, Se, and Mo. Procedures developed specifically for these elements are included in the report.

There has been an interest in evaluating the potential of electrochemical techniques, particularly polarography and anodic stripping, for sludge analysis. These techniques were investigated and results and preliminary conclusions are presented.

Flameless atomic absorption is considered to be important for the analysis of sludge. This technique may have an important application in the determination of total metals which are difficult to analyse by flame methods. However, flameless atomic absorption is investigated as a possible method of identifying the forms of metals which occur in sludge. In this regard, a quartz "T" tube furnace has been developed which can be used for thermal volatility studies and gas chromatographic studies of metal compounds in sludges. As a spin-off benefit of this study, data will be obtained for potential metal losses to stack gases because of incineration, if this method is used for sludge disposal. Early results of this investigation are included in this report.

In category B, available chemical sludges are being routinely analysed for metals. A tabulation of results from four new sewage treatment plants in Ontario is included in this volume.

#### Summary of Research Report No. 51, Volume IV

Project 72-5-3: HEAVY METALS IN AGRICULTURAL LANDS RECEIVING CHEMICAL SEWAGE SLUDGES (Analytical Methods for Sewage Sludge Analysis) - J.C. Van Loon, University of Toronto

The objective of this study was to review and develop analytical methods for sewage sludge analysis. It had been agreed in earlier work on this overall project that knowledge of the form of metals in waste and environmental samples is of great importance. This led to emphasis, during this stage of the study, on the development of simple equipment and methods to initiate metal speciation studies.

Procedures developed in last year's report and labelled as "provisional" were studied in depth. The mercury method is now acceptable as recorded. The As/Se procedure has been modified as a result of further investigation.

Some environmentally important metals, e.g., silver, tin and vanadium, are not readily analyzed in sludges by conventional flame atomic absorption. Nonflame atomic absorption methods were developed for silver and vanadium. The hydride method for tin was extensively investigated, but further work will have to be done before satisfactory results can be reported.

It is emphasized that obtaining total heavy metal data on wastes and environmental samples does not necessarily allow a meaningful interpretation of the environmental impact of the metals. This is patently evident in published studies on lead and mercury.

Work resulting from this project, and by other researchers, suggests that combining atomic absorption as a detector with powerful separational techniques is a relatively simple and inexpensive method of doing metal speciation work.

Metal speciation studies are much more difficult than studies involving total heavy metals. It is demonstrated that using atomic absorption spectroscopy as a detector does not guarantee a quick solution to metal speciation problems. The opinion is expressed that atomic absorption spectroscopy will, in time, make as great a contribution to metal speciation studies as it did in the past decade to the routine analysis of total metals.

It is demonstrated that sludges can be dry-ashed at 450°C without fear of loss of cadmium, lead or appreciable zinc. When arsenic is to be determined, dry-ashed should not be used. Data also make it clear that incineration at temperatures usually employed will release large amounts of arsenic, cadmium, lead, mercury and zinc.

## PROJECT SUMMARY

Project Title : Land Disposal of Sewage Sludge  
Project Leader : T.E. Bates  
Scientific Liaison Officer: S.A. Black  
Project Number : 72-5-17  
Contractor : University of Guelph  
Departments of Land Resource Science  
and Microbiology  
Contract Time : 1972-1978  
Project Status : Continuing  
Status of Reports : Reports are published in the Canada-Ontario  
Agreement Research Report Series.  
Volume I Report No. 16  
Volume II Report No. 24  
Volume III Report No. 35  
Volume IV Report No. 60  
Volume V Report being published

### Description and summary

This study was designed to evaluate the effects of sewage sludge application at various rates, to agricultural lands. The specific objectives were to determine the maximum rate of sludge application, on an annual and perennial crop, as influenced by soil texture, which will maintain crop quality and yield and avoid contamination of the environment.

Experiments are being conducted on three soils differing in texture, a loamy sand, a loam and a clay loam although the clay loam site has now been eliminated from the study. Specific experiments are being undertaken to determine:

1. the losses or removal of nitrogen from soil plant systems in the field;
2. the availability and removal by crops of nutrients and heavy metals applied in different sludges;
3. the occurrence of organisms derived from sludges on crop plant surfaces; and,

4. the influence of sludge constituents on soil characteristics with depth in soil profiles in the field.

The study also includes runoff studies for sludge transport determination and greenhouse studies to evaluate extractive techniques for heavy metals and to determine metal-crop relationships on a short term accelerated basis.

#### Results and conclusions

As the project is continuing, the following should only be considered as tentative conclusions based upon the first four years of investigation:

**Runoff Studies:** The coincidence of a runoff event and the full sludge application results in elevated losses of nitrogen, phosphorus, acid-extractable metals and COD.

**Field Studies:** In general, crop growth is at least as good with sludges as with chemical fertilizers. The three chemical sludges, lime, iron and aluminum produced similar yields although the iron sludge tends to advance slightly early growth and maturity of corn. Crop yields respond to nitrogen application from both ammonium nitrate and from sewage sludge.

#### **Greenhouse**

**Studies:** High rates of sludge application reduce crop yield. Comparison of various chemical extractants as measures of metal availability to plants show acetic acid as a promising extractant for nickel.

#### **Nitrogen**

**Studies:** In general, about twice as much nitrogen appears to be required from sludge as from ammonium nitrate to produce the same yield in grass or corn. Nitrate nitrogen concentrations in grass and corn stover approached toxic levels for animals at the highest rates of sludge application.

#### Phosphorus

Studies: Sludges increase the sodium bicarbonate extractable phosphorus in soil quite markedly. The phosphorus in calcium sludge appears to be appreciably more available in Ontario soils than that supplied in iron or aluminum sludges.

#### Bacterial

Studies: These studies did not conclusively demonstrate increased populations of indicator organisms on plants or in runoff waters from sludge treated soils.

There appears to be a tendency in the greenhouse for plant metal levels to increase in later crops with high rates of the highest metal sludges. For a long time there was no tendency for the metal level to increase from one crop to the next. Now it appears to be increasing but only for the sludges which are highest in metal content. This will be interesting to follow over the next few crops.

#### Summary of Research Report No. 16, Volume I

Project 72-5-17: LAND DISPOSAL OF SEWAGE SLUDGE (November 1972 - March 1973) - University of Guelph

This project was designed as the first part of a six year study to determine the rates at which sludge from lime, aluminum sulphate and ferric chloride treated sewage may be safely applied to agricultural land. The following aspects of sludge application to soil were to be investigated: rate of nitrogen transformation to soluble forms when chemical sludges are incorporated into sand-soil mixtures; bacterial contamination of runoff and groundwater; the macromorphology, micro-morphology, and chemical and physical states of the soil before sludge application; the effect of sludges on plant growth; and nutrient and heavy metal uptake by plants.

Field experiments were planned for 1973 with both corn and grass as crops, using the three chemically treated sludges on three different soils. Although no sludge was applied during the period of study described in this report, appreciable preparation and installation

of facilities for these experiments occurred. A runoff study was initiated on two different slopes with two rates of application of ferric chloride treated sludge. A greenhouse study was also in progress using three rates of the three sludges on two soils limed to different pH levels. Rates of the three sludges applied in field and greenhouse were based on the nitrogen content.

A preliminary study on nitrogen transformation showed that Fe and Ca treated sludges apparently do not inhibit nitrogen transformation in soil, whereas the Al treated sludge did. The rate of appearance of nitrate-nitrogen was greatest for the Fe treated sludge. The results suggest that the rate of N transformation in the field may be dependent on the type of sludge applied.

Runoff experiments were conducted on field plots with 2% and 6% slopes. There were indications that the iron-precipitated sludge decreased water infiltration, and that the runoff loss of nutrients (5% of application) tended to be relatively less than the runoff loss of water (25% of precipitation). Phosphorus and heavy metal losses from the sludges used appeared to be insignificant.

Soil characterization studies were initiated to determine the macromorphology, micromorphology, and chemical and physical states of the soils before sewage sludge was applied. As of March 1973, the macromorphology of each soil profile had been described, particle size distribution analyses were partially completed, and organic matter content and pH values with depth had been determined. These data are given in the report. Microbial examinations of the three different sludges and the runoff waters from sludge treated plots were conducted. In general, the numbers of bacteria of the various groups detected in the sludge were much greater than the numbers found in the runoff samples. The relationship between the fate of organisms, time of application, amount of sludge applied, and the physical environment is subject to many variables.

Project 72-5-17: LAND DISPOSAL OF SEWAGE SLUDGE (April 1973 - March 1974)  
- University of Guelph

The objectives of the project described by this report were to determine the maximum rates of sludges, containing phosphorus-removal chemicals, which may be applied to agricultural soils without polluting ground and surface waters with elements or organisms pathogenic to humans and animals, and without reducing the quantity or quality of the crops produced.

Runoff studies were conducted with sewage sludges applied in fall, winter and spring; field rate and source of sludge studies were carried out with brome grass on a loam soil and with corn on a loam, a sandy loam and a clay loam soil. A greenhouse trial with different rates and sources of sludge on two soils at three pH levels is also reported. Fluid digested sewage sludges from calcium oxide treatment of Newmarket sewage, aluminum sulphate treatment of Point Edward sewage and ferric chloride treatment of North Toronto sewage were used. Chemical analyses of the sludges, soil nitrogen, crop yields and nutrient and metal content of crops are presented along with microbial studies of the sludges and the crops grown. Detailed descriptions of the soils used are also presented.

There was a marked growth response to sewage sludge in the greenhouse and in the field brome grass trial. Corn yields were increased by sludge application at the Elora and Milton sites.

An exception to the above occurred in three trials where a poor growth response to the aluminum sludge from Point Edward was observed. Nitrification studies and plant nutrient analyses suggested that, when applied at the same rate of total nitrogen as the other sludges, the Al sludge supplied less available nitrogen to the crops. Aluminum can be toxic to plants, but there was no evidence of this in the greenhouse trials. However, in most of the trials crop yields did not increase with increasing rates of the Al sludge, suggesting that some toxic factor was involved. None of the nutrients or metals analyzed

appeared to be the cause. It is probable that some other constituent of the Point Edward sludge, unrelated to aluminum treatment, was involved in its apparent toxicity to plants.

The sludges applied resulted in rather small applications, on an acre basis, of the elements chromium, mercury, manganese, and nickel, and no effect of these metals was noted in the concentrations in plants. Somewhat larger amounts of lead were added with the North Toronto sludge, but did not affect the content of plants. Little effect was expected in this first year of application.

Zinc and copper contents of the sludges were lower than those reported for a number of Ontario sludges, but affected concentrations in plants to some extent. In the greenhouse trial, sludge did not affect the zinc concentration in barley at low soil pH. At high soil pH, the zinc concentrations were lower than at low pH. However, at high pH the zinc concentration in barley increased with increases in rate of sludge, and this also occurred in the corn trials. In the greenhouse, copper increased with increasing rates of sludge. Zinc and copper are known to cause problems after continued applications of high rates of sewage sludge. While the concentrations in plants were far from toxic in these trials, it was not expected that concentrations would be affected in the first crop with the quantities of copper and zinc applied.

Although it has always been known that sewage sludge contains appreciable phosphorus, it is also well known that mineral soils have an exceptional capacity to bind this element. There has been little suggestion that phosphorus content might limit rates of sludge application. The amounts of phosphorus applied in the sludges used in this study were from 2.5 to 3.5 times as high as the highest rate recommended for corn in Ontario. Some effort will be required to determine how long it will take for these rates of phosphorus to exceed the fixation capacity of Ontario soils.

A considerable quantity of nitrate-nitrogen remained in the soil profiles at the end of the growing season (October sampling). This nitrate-nitrogen not absorbed by the crop may be leached to the sub-surface water and/or lost as a gas through denitrification.

There has been some concern that the application of sewage sludges, particularly calcium sludge, would affect boron availability. It seemed possible that boron might be less available with the high pH resulting from the use of the calcium sludge. However, in the greenhouse trial, boron concentration increased slightly with increasing rates of calcium sludge. There was little effect of the sludges on boron concentration in corn. Boron is readily leached and is therefore not likely to build up in Ontario soils from year to year. On the basis of this limited experience, it does not seem likely that the use of sludge at moderate rates under Ontario conditions will cause serious deficiencies or toxicities of boron. In drier climates it is possible that boron would accumulate in the soil profile.

Studies at this stage have not conclusively demonstrated increased populations of indicator organisms on plants or in runoff waters from sludge treated soils.

Runoff losses in 1973 were generally less than would be expected in a normal year. High rates of application greatly increased nutrient runoff and this emphasizes the importance of restricting application rates to soil requirements for crop growth. Metals losses were small with the sludges and rates used in this study.

Sewage sludge has a reputation for being variable in composition and this is a major concern in the development of recommendations for its use on farm land. It is difficult, if not impossible, to recommend optimum or even permissible rates of an unknown product. The truckloads of sludge sampled and analyzed in these studies were a very small sampling of what is spread in Ontario. In the analyses performed, the samples of the calcium sludge from Newmarket illustrated the variability problem and the samples of the iron sludge from North Toronto illustrated the type of uniformity in composition which is desirable. If the degree of uniformity in composition apparently attained at the North Toronto plant could be attained across the entire province, a very serious problem in the acceptance of the use of sludge on agricultural land would be solved.

Project 72-5-17: LAND DISPOSAL OF SEWAGE SLUDGE (April, 1974 - March, 1975)  
- University of Guelph

This report covers runoff studies with fall, winter and spring applied sewage sludge, and field rate and source of sludge studies with brome grass on a loam soil and with corn on a loam, a sandy loam and a clay loam soil. A greenhouse trial with different rates and sources of sludge on one soil at two pH levels is also reported. Nine fluid digested sewage sludges were used.

Chemical analyses of the sludge, soil nitrogen, crop yield and nutrient and metal content of crops are presented along with microbial studies of the sludge and the crops grown. Detailed descriptions of the soils used are also presented.

In runoff studies, losses of nitrogen and nutrients were low in 1974, lower than 1973. One runoff event immediately following fall sludge application resulted in appreciable losses of nutrients, metals and COD.

In the field, crop responses to the sewage sludge were similar in most cases to those from chemical fertilizers. The three chemically treated sludges produced similar yields, although the iron sludge tended to advance early growth and maturity of corn slightly. In one trial, where soil structure was a problem, sludges produced appreciably higher yields than chemical fertilizers. There was no evidence of poor growth with the aluminum sludge in 1974 in any of the trials. In the greenhouse, sludge at high rates of application caused salinity problems when the soils were not leached. Salinity is not expected to cause problems in the field in Ontario, but could pose a serious problem in dry areas of western Canada.

The calcium sludge tended to increase soil pH in the field and greenhouse even on soil of pH 7.1. The aluminum and iron sludges lowered soil pH, but less than one-quarter as much as similar rates of nitrogen from ammonium nitrate.

In general, about twice as much nitrogen appeared to be required from sludge as from ammonium nitrate to produce a particular

yield or nitrogen content in grass or corn in the field in 1974. One might expect that, as each year passes, the sludge nitrogen would compare more favourably with ammonium nitrate due to the gradual release of nitrogen from the accumulation of organic matter. Nitrate nitrogen concentrations in grass and corn stover approached toxic levels for animals at the highest rates of sludge application.

Sludges increased sodium bicarbonate extractable ("plant available") phosphorus in soil quite markedly. This effect was appreciably greater with the calcium sludge although it supplied less total phosphorus than the other sludges in most cases. Phosphorus concentration in crops was slightly higher with the calcium than with the other sludges, but even the lowest rates of sludges produced adequate phosphorus concentrations in plants and increasing rates of sludge did not, in general, increase phosphorus concentrations.

The phosphorus in calcium sludge appears to be appreciably more available in Ontario soils than that supplied in iron or aluminum sludges. With the large amounts of phosphorus in sludge, this greater availability may be a disadvantage where sludges are applied repeatedly to the same land.

The Midland sludge supplied appreciably more boron than other sludges and could pose a toxicity problem if used at high rates for certain crops, or if used in dry areas where boron could accumulate.

Cadmium concentrations were quite low in the field trials but the use of high cadmium sludges in the greenhouse resulted in appreciable uptake. Of particular concern was the high cadmium concentration in the second crop of grass on the treatment which received only one application of sludge at the 1600 kg N/ha rate before the first crop was seeded. This produced higher cadmium concentrations than two applications of 1600 kg N/ha, one before seeding each crop. Thus, cadmium appeared to become more available with time after application.

Copper concentrations were increased by sludge applications, increases being, in general, related to copper additions. The sludges which were used in the field trials were low in copper. They increased copper content of crops by no more than the increase with ammonium nitrate.

Nickel concentrations in crops increased quite markedly with addition of nickel in sludges. The calcium sludge from Midland, high in nickel, increased concentrations of nickel in ryegrass quite markedly even at high soil pH. Nickel, like cadmium, appeared to become more available with time.

Zinc concentrations were increased by sludge additions in the field and greenhouse, although in the greenhouse some low zinc sludges also reduced zinc concentrations in grass, probably by raising soil pH. At high rates of application, zinc appeared to become more available with time after application in sludge.

Potassium, calcium, magnesium, manganese, iron, aluminum, chromium and mercury concentrations in crops were all significantly affected by treatment in one or more trials but effects were variable and small. There was no evidence that aluminum sludges produced high aluminum concentrations in crops. Chromium concentrations in crops increased quite appreciably on a percentage basis in one trial but the concentrations were still quite low.

In the field trials, less nitrate accumulated in the soil under grass than under corn. More nitrate appeared to be produced by sludges containing the largest portion of their nitrogen in ammonium form. In general, nitrate concentrations in soil solution were quite high, but movement was less than in 1973, probably because of the lower rainfall in July and August in 1974. The nitrate concentrations were much greater in the silt loam and clay loam profiles than in the sandy loam, for reasons that are not clear. In the fall of 1973, nitrate appeared to be lost from the clay loam profile, probably by denitrification, but in 1974 there was no apparent loss.

In laboratory nitrification studies, nitrate production continued for at least 52 weeks. The rate of nitrate production varied among sludges but differences were not related to chemical treatment applied to sewage for phosphate control or to ammonium content. The Point Edward aluminum sludge collected in 1973 gave a low rate of nitrate production. The Point Edward iron sludge collected in 1974 also gave a low rate of nitrate production, although not as low as the 1973 sludge.

Comparisons of various chemical extractants as measures of metal availability to plants show acetic acid as a promising extractant for nickel. Further work is required on the other metals.

Iron in the iron sludge is crystallized, based on chemical extraction, microprobe analysis and X-ray. Where the sludges have been applied on the soil surface in the bromegrass trial, the ferric phosphate crystals appear to be decomposing and the iron may chelate with organic matter.

Where the sludge has been surface applied, calcium, aluminum and iron all appear to be moving into the soil; calcium has moved by as much as twelve inches in two years.

Examination of the sludges before application to soil showed inorganic minerals and particulate matter. Some fibrous material in the aluminum sludge appears to be organic.

#### Summary of Research Report No. 60, Volume IV

Project 72-5-17: LAND DISPOSAL OF SEWAGE SLUDGE (April, 1975 - March, 1976) - University of Guelph

This section of the overall study of land disposal of sewage sludge was designed to determine rates of sewage sludge which may be safely applied to certain slopes at specified times of the year. The report discusses the results from the third year of field runoff studies with fall, winter and spring application of fluid sewage sludge on land cropped with grain corn. Runoffs of water, soil, nutrients and metals have been measured.

The report also covers field rate and source studies with three sludges resulting from treatment of sewage with calcium hydroxide, ferric chloride and aluminum sulphate for phosphorus removal.

One experiment involves surface sludge applications on a loam soil on which bromegrass is grown, and three trials involve corn on a loam, a sandy loam and a clay loam soil.

In one greenhouse experiment nine fluid sewage sludges, selected for their high metal content, were applied to a soil previously adjusted to two pH levels. Five crops of ryegrass have been grown with sludges added before each crop.

Crop growth and nutrient and metal uptake have been studied in the trials along with micropedological studies of the soils. The sludges and field-grown crops have been monitored for pathogenic organisms.

Field experiments and laboratory studies have been used to estimate the nitrogen availability from sludges and the rates of volatilization of nitrogen from surface applied sludge in the field.

A greenhouse experiment has also been run on a group of soils varying in metal content. The soils were extracted with various chemicals in an effort to find suitable extractants for plant available cadmium, copper, nickel, lead and zinc.

Total runoff in 1975 was similar to 1973 and 1974, as were nitrogen, phosphorus and metal losses. Metal losses were small, and mostly associated with summer losses of soil solids. Sludge application has no effect on total runoff volume.

In the field rate and source studies the bromegrass had slightly higher yield with sludge than with ammonium nitrate. At low rates of application the calcium sludge tended to produce lower yields, and higher yields at higher rates of application than the other sludges, a trend which had been apparent in 1974. Corn yields were little affected by nitrogen or sludge in 1975.

The sludges markedly increased sodium bicarbonate-extractable "plant available" soil phosphorus, with the calcium sludge being much more effective than the other sludges. Phosphorus concentrations in the crops were high and unaffected by treatment.

Cadmium content of both grass and corn stover was increased by sludge application, the effect being highest with the sludge supplying the most cadmium. Nickel, chromium and copper were increased in some plant tissues at some sites, but the effects were not consistent. Zinc concentration increased in bromegrass, corn grain, and at one site in corn stover. Molybdenum in plant tissue appeared to increase with sludge application.

In the greenhouse study, increased rates of sludge applied at one time increased the concentrations of metals in ryegrass. Repeated cycles of sludge application and cropping did not increase metal concentrations in the ryegrass from one crop to the next (up to the fifth crop) at any of the rates studied.

Several extractants could be used to predict cadmium, nickel and zinc concentrations in Swiss chard, predictions being improved in most cases where pH, clay content, organic matter and cation exchange capacity were also measured. Nitrilotriacetic acid is probably the most universally acceptable extractant for all three of these metals on the group of soils studied.

Electron microprobe, scanning electron microscope and light microscope investigations lead to the conclusion that surface accumulations in the greenhouse soils were a mixture of salt evaporites and microorganisms.

Salmonella species were detected during the 1975 season in sludges (11 of 15 samples) and corn (4 of 24 plot samples). Salmonella species were not detected in the runoff waters (132 samples) or in the grass samples (36 plot samples).

During the longer period, May 1973 to March 1975, salmonella species were detected in 20 of 54 samples of sludge, one of 484 samples of runoff waters, two of 96 samples of grass, and four of 24 samples of corn.

## PROJECT SUMMARY

Project Title : Chemical Sewage Sludge Disposal on Land - Lysimeters

Project Leader : D.B. Cohen

Project Number : 72-3-6

Contractor : Fisheries and Environment Canada  
Wastewater Technology Centre

Contract Time : 1972 - 1978

Project Status : Continuing

Status of Reports: No reports yet issued. It is expected that three reports will be issued on this Project. Volume I is currently in the process of publication authored by V.K. Chawla, D.N. Brant, D. Liu and D.B. Cohen. Papers already published are as follows:

1. Chawla, V.K., D.N. Bryant and D. Liu, "Disposal of Chemical Sewage Sludges on Land and their Effects on Plants, Leachates and Soil Systems". Canada-Ontario Agreement Conference Proceedings No. 2, Sludge Handling and Disposal Seminar, Toronto, Ontario, September 18-19, 1974.
2. Cohen, D.B., and D.N. Bryant, "Effects of Applying Digested Sludges to Agricultural Land - Lysimeter Studies", presented at Sludge Handling and Disposal Seminar, Calgary, Alberta, February 16-18, 1977.

### Description and summary

A lysimeter experiment was initiated at the Wastewater Technology Centre, Burlington, during 1972. Cylindrical fibreglass lysimeters 30 cm diameter, 180 cm deep were housed in an environmentally controlled trailer. The tops of the lysimeters projected 7.6 cm above the roof of the trailer subject to normal ambient and atmospheric conditions. Facilities were provided at the bottom of the lysimeters for leachate collection.

The objectives of this study are:

1. to investigate crop response to sludge application rates;
2. to investigate the effects of sludge on the concentrations of nutrients, minerals and metals in plant, soil and leachate; and,
3. to monitor the effect of sludge applications on microbial quality of soil and leachate.

The experiment was designed as a randomized block of 66 lysimeters using three replications of two soil types, eleven fertility treatments consisting of three sludge types, three sludge loading rates and two controls (with and without NPK commercial fertilizer). The sludge consistency (liquid), soil types (loamy sand and silt loam), and agricultural crop (orchard grass) were chosen to enable subsequent comparison with field studies carried out by the University of Guelph. Sludge types were chosen to include the three most common chemicals used for phosphorus removal (alum, iron and lime). Sludge loading rates (kg TKN/ha) were chosen to closely approximate the soluble nitrogen requirement for crop production at the lowest application rate, with the medium and high rates double and triple the low rate.

Liquid sludge was applied three times in 1973, four times in 1974 and five times in 1975 and 1976, each time at 100, 200 and 300 kg TKN/ha resulting in cumulative loading by 1976 of 5100 kg TKN/ha at the highest rates.

Crop yields were determined and the plant tissue was analyzed for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), manganese (Mn), iron (Fe), aluminum (Al), zinc (Zn), copper (Cu), nickel (Ni), cadmium (Cd), chromium (Cr), and lead (Pb).

Leachate was collected periodically to represent different periods of the year. Leachate quality was monitored for pH, conductivity and chemically analyzed for nitrate nitrogen ( $\text{NO}_3\text{-N}$ ), ammonium nitrogen ( $\text{NH}_4\text{-N}$ ), nitrite nitrogen ( $\text{NO}_2\text{-N}$ ), total Kjeldahl nitrogen (TKN), chloride (Cl), sulphate ( $\text{SO}_4$ ), total carbon (TC), total organic carbon (TOC) as well as P, K, Ca, Mg, Na, Fe, Al, Mn, Zn, Cu, Ni, Cr, Cd, and Pb.

Samples of sludge, soil and leachate were collected for microbial analysis. Sludge amended soil samples (2 cm cores) to a depth of 61 cm were taken in April 1974 for microbial analysis. These cores were subsectioned into 2.5, 7.5, 15.0, 25.0, 37.5, and 60.0 cm depth fractions for the study of microbial vertical movement in the soils.

## Results and conclusions

- (a) At least 200% of NPK control application rates must be applied as fluid sludge to obtain crop yields equivalent to NPK treatment. The residual effects of cumulative sludge applications is evident as 89% of sludge treatment yields exceeded NPK in 1976 (loamy sand) compared to 22% in 1973.
- (b) Orchard grass concentrations (mean of all sludges) of Cd, Cr, Cu, Ni, Pb and Zn did not exceed suggested maximum tolerance or toxic concentrations.
- (c) Zn and Cu uptake by orchard grass at the highest sludge loading rate was twice that of the NPK treatment. The uptake of metals by orchard grass receiving alum, iron or lime sludges reflect TKN uptakes rather than sludge metal loading rates.
- (d) Leachate volume losses from orchard grass varied inversely with crop yields and sludge loading rates.
- (e) Leachate maximum concentrations of Cd, Cr, Cu, Ni, Pb and Zn did not exceed drinking water standards. Metal concentrations (mean of all sludges) were similar to the NPK control treatment. No increasing concentration trend for any metal monitored was observed from 1973 to 1976.
- (f) Nitrogen as  $\text{NH}_4\text{-N}$  rarely exceeded the drinking water maximum permissible concentration (MPC) of 0.5 mg/l in leachate. The nitrate  $\text{NO}_3\text{-N}$  MPC of 10 mg/l was not exceeded during 1974 or 1975, but increased to greater than the MPC during 1976 where the high rate of alum and iron sludges was applied.  $\text{NO}_3\text{-N}$  in leachate from lime sludge never exceeded 10 mg/l and was significantly lower than  $\text{NO}_3\text{-N}$  from alum or iron sludge applications.
- (g) Soluble P occasionally exceeded the MPC of 0.1 mg/l only when the high rate of alum sludge was applied to loamy sand.
- (h) TOC in leachate increased over time to exceed 50 mg/l in 1976 from the highest sludge loading rates. Static bioassay toxicity tests using *Daphnia* showed no toxicity in leachate samples having high TOC values.

- (i) During 1973-74 the heterotrophic bacteria counts in leachate remained fairly constant for all treatments and were of soil origin. The sludge microorganisms were retained in the top 15 cm layer of both solids. The 7.5 to 60 cm soil layers were completely free of coliforms.

Several years of monitoring plant tissue chemical concentrations and leachate quality are required to evaluate the long term affects of increasing sludge loading to soils. Intensive research is required to assess the migration and complexing of various sludge constituents within the soil profile.

## PROJECT SUMMARY

Project Title : Sewage Sludge Interactions with Soil Materials

Project Leader : M.D. Webber

Project Number : 72-5-18

Contractor : Agriculture Canada  
Soil Research Institute

Contract Time : 1972 - 1976

Project Status : Completed

Status of Reports: No report yet issued.  
Papers already published:

1. "Extractable Metals in Mixtures of Soil and Sewage Sludge", Canada-Ontario Agreement Conference Proceedings No. 2, Sludge Handling and Disposal Seminar, Toronto, Ontario, September 18-19, 1974, pages 249-266.
2. "Metal Extractability from Sludge-Soil Mixtures", Proceedings of International Conference on Heavy Metals in the Environment, Toronto, Ontario, October 1975.

### Description and summary

The objectives of this study were: (1) to measure the solubilities of metals added to soils in sewage sludges and (2) to determine whether molybdenum contained in sewage sludges would leach from soils limed to pH 7.

Sludge sources were chosen to include no chemical treatment for phosphorus removal, and lime and iron treatment. Grab samples were collected from the Fergus and Ottawa (no chemical), Midland and Newmarket (lime), and Guelph, North Toronto, Sarnia and Stratford (iron) pollution control plants.

Soils with pH values ranging from 4.3 to 5.4 were chosen to provide one group of three with low clay contents and a range from 1 to 10% organic matter, and a second group of three with high clay contents and a range from 1.7 to 16.2% organic matter.

Sludge was mixed with soil and: (1) incubated moist for various periods of time under various conditions of temperature and

aeration, and (2) leached with a neutral salt approximating the concentration of soil solution. Metal solubilities in incubated sludge-soil mixtures were determined by extraction and molybdenum was measured in the leachates.

#### Results and conclusions

1. (a) Adding sewage sludges increased the levels of extractable cadmium, zinc, copper, nickel, lead and molybdenum in soils in relation to the amounts of these metals added. There were no consistent changes in extractable cobalt and no extractable chromium or tin were detected.
- (b) Extractable zinc, nickel, lead and cobalt were related to soil organic matter content and extractable zinc was related to clay content.
- (c) Incubating sludge-soil mixtures under a variety of simulated field conditions indicated that the levels of extractable metals were largely independent of the weather conditions likely to occur in Ontario. Anaerobiosis generally reduced metal solubilities but is unlikely to occur widely under field conditions.
- (d) Liming reduced the levels of extractable zinc and nickel but not of copper, lead and cadmium.
- (e) Adding large amounts of newspaper to the sludge-soil mixtures caused little change in the levels of extractable metals.
- (f) Repeated applications of sludges containing large amounts of metals caused very high levels of extractable metals.
2. (a) Leaching removed molybdenum from sludge treated soils and the loss was most rapid from the soil with the lowest clay and organic matter contents.

Land applications of sewage sludges will increase the solubilities of cadmium, zinc, copper, nickel, lead and molybdenum in soils and uncontrolled application of sludges containing large amounts of these metals will cause excessive increases. High metal solubilities in soils are likely to cause crop and animal toxicities; however, further work is required to define the critical levels. Molybdenum

leached slowly from soils limed to pH 7 and high levels of that metal are not expected to persist in agricultural soils.

#### Abstract of Report on Project 72-5-18

SEWAGE SLUDGE INTERACTIONS WITH SOIL MATERIALS - Soils Research Institute, Agriculture Canada

Eight anaerobically digested Ontario sewage sludges, including two lime, four ferric chloride and two without P-removal chemicals were mixed with six soils and incubated in the laboratory under a variety of simulated field conditions. The sludges exhibited a wide range of metal contents and the soils a wide range of chemical and physical properties. Following incubation, the sludge-soil mixtures were extracted with 0.005M DTPA, 0.5N HOAc, 0.05M EDTA and 0.01M  $\text{CaCl}_2$  to measure Cd, Zn, Cu, Ni, Pb, Co, Cr and Sn solubilities, and with acid ammonium oxalate, 1N  $(\text{NH}_4)_2\text{CO}_3$  and 0.02M KCl to measure Mo solubility. In addition, columns of soils limed to pH 7 and treated with sludges were leached with 0.02M KCl to determine the potential for Mo movement.

Adding sludge increased the levels of extractable Cd, Zn, Cu, Ni, Pb and Mo in soils in relation to the amounts of metals added. The sludges contained small amounts of Co and caused no consistent changes in extractable Co, while Cr and Sn were not detected in any of the extracts. DTPA-extractable Zn, Ni, Pb and Co increased with increasing organic matter contents of the soils whereas DTPA- and HOAc-extractable Zn decreased with increasing clay contents.

Incubating sludge-soil mixtures under a variety of simulated field conditions indicated that the levels of extractable metals were largely independent of weather conditions likely to occur in Ontario. They were approximately the same following incubation at  $-15^\circ\text{C}$ ,  $10^\circ\text{C}$ ,  $25^\circ\text{C}$ , and alternate  $-15^\circ\text{C}$  and  $25^\circ\text{C}$ . Anaerobiosis generally reduced metal solubilities but is unlikely to occur widely under field conditions. Liming reduced the levels of DTPA-extractable Zn and Ni but not of Cu, Pb or Cd. Adding a large amount of newspaper to the sludge-soil mixtures caused little if any change in metal solubilities. Repeated

applications of sludges containing large amounts of metals caused very high levels of extractable metals.

Leaching removed Mo from sludge treated soils and the loss was most rapid from the soil with the lowest clay and organic matter contents. No Cd was detected in the leachates.

Land application of Ontario sewage sludges will increase the solubilities of many heavy metals in soils and uncontrolled application of sludges containing large amounts of these metals will cause excessive increases. High metal solubilities in soils are likely to cause crop and animal toxicities; however, further work is required to define the critical levels. Molybdenum leached slowly from soils adjusted to pH 7 and high levels of that metal are not expected to persist in agricultural soils.

## PROJECT SUMMARY

Project Title : Biochemical Characteristics of Digested Chemical Sewage Sludges

Project Leader : V.K. Chawla

Project Number : 73-3-11

Contractor ; Fisheries and Environment Canada  
Wastewater Technology Centre

Contract Time : 1973 - 1974

Project Status : Completed

Status of Reports: The report on Project 73-3-11 is included with the report on Project 74-3-16.  
Papers already published are as follows:

1. Liu, D., V.K. Chawla and A.S.Y. Chau, "Chlorinated Hydrocarbon Pesticides in Chemical Sewage Sludges". Proceedings of the 9th Annual Conference on Trace Substances in Environmental Health, University of Missouri, Missouri, Mississippi, June, 1975.
2. Chawla, V.K., J.P. Stephenson and D. Liu, "Biochemical Characteristics of Digested Chemical Sewage Sludges". Canada-Ontario Agreement Conference Proceedings No. 2, Sludge Handling and Disposal Seminar, Toronto, Ontario, September 18-19, 1974.
3. Chawla, V.K. "Characterization of Chemically Precipitated Digested Sewage Sludges", presented at the NATO-CCMS Workshop on Advanced Wastewater Treatment, Ottawa, 1974.

### Description and summary

The objective of this study was to assess the biochemical characteristics and variability of anaerobically digested chemical sludges.

Sludge sources were chosen to include the three most common chemicals used for phosphorus removal (alum, iron and lime). Grab samples were collected each week from North Toronto (iron), Newmarket (lime), Sarnia (alum), and Point Edward (alum; lime + iron) from January 1973 until March 1974.

The samples were monitored for pH, conductivity, total, volatile and fixed solids, then chemically analyzed for total Kjeldahl nitrogen, nitrite, nitrate and ammonium nitrogen, total, ortho and

organic phosphorus, total and organic carbon, chloride, sulphate, sodium, potassium, magnesium, calcium, iron, aluminum, manganese, copper, nickel, zinc, chromium, cadmium and lead.

Microbial analysis was carried out for the identification and density of various sludge bacteria in samples collected from June to September 1973.

Further to chemical and microbial analysis, concentrations of eleven organochlorine pesticides, as well as polychlorinated biphenyls were determined from June 1973 to March 1974.

### Results of work

- (a) TKN and total P concentrations increased at each treatment plant over this study period. Seasonal variations were not evident in  $\text{NH}_4\text{-N}$  concentrations. TKN,  $\text{NH}_4\text{-N}$  and total P concentrations varied appreciably in digested sludges as compared to reported nitrogen and phosphorus variations in domestic raw sewage. The overall mean ranges of concentration for TKN,  $\text{NH}_4\text{-N}$  and total P were 1150 to 2510; 290 to 744; and 665 to 1420 mg/l, respectively, in all four sludges.
- (b) Heavy metal concentrations varied randomly. Specific trends observed at Point Edward did not represent steady state conditions.
- (c) The populations of aerobic heterotrophic bacteria were relatively constant and their concentrations ranged from  $7.5 \times 10^9$  to  $4.1 \times 10^{10}$  per 100 ml. Coliform bacteria accounted for less than 0.1 percent of the total heterotrophic bacteria in all cases.
- (d) Eleven organochloride pesticides were detected in all four sludges studied - the predominant pesticides were DDT, DDE, Chlordane and Heptachlor. Industrial waste appears to be the main source of pesticides as is evident by higher values from Sarnia and North Toronto compared to Point Edward and Newmarket; however, all concentrations are considered minimal.
- (e) Overall mean concentrations of PCB's in all four sludges ranged from 74 (Newmarket) to 1122  $\mu\text{g/l}$  (Sarnia).
- (f) Sludge from Point Edward, North Toronto, and Newmarket had petroleum hydrocarbon concentrations of 7580, 524 and 434 mg/l, respectively. Very high concentrations from the Point Edward plant were unexpected.

- (g) The findings suggest that parameters of interest must be characterized at individual plants to obtain reliable estimates of true population means and deviations. Routine monitoring can identify long term trends within sludge characteristics.

#### Results and conclusions

Results have demonstrated the variabilities in constituent concentrations which may be encountered in grab samples of sludges collected over a relatively long period. The few treatment plants (four) assessed are considered insufficient to categorize sludges from Ontario treatment plants of similar size and type. Further studies are required:

- (1) to identify and compare the sources of constituent variability in anaerobically digested sludges by determining whether observed variations arose from analytical measurements, from changes in the composition with time, or from inherent heterogeneity;
- (2) to determine the number of samples and a sampling frequency required to estimate constituent concentrations in digested sludges with a given degree of precision. This recommendation resulted in Project 74-3-16.

## PROJECT SUMMARY

|                                    |   |                                                                                       |
|------------------------------------|---|---------------------------------------------------------------------------------------|
| <u>Project Title</u>               | : | Land Application of Sewage Sludge under Adverse Conditions                            |
| <u>Project Leader</u>              | : | E.R. Simonen                                                                          |
| <u>Scientific Liaison Officer:</u> | : | S.A. Black                                                                            |
| <u>Project Number</u>              | : | 73-5-9                                                                                |
| <u>Contractor</u>                  | : | Regional Municipality of Niagara Public Works Department                              |
| <u>Contract Time</u>               | : | 1973 to 1975                                                                          |
| <u>Project Status</u>              | : | Completed                                                                             |
| <u>Status of Report</u>            | : | Report is published in the Canada-Ontario Agreement Research Report Series as No. 53. |

### Description and summary

The study began with a literature review to determine the types of equipment currently used in applying liquid sewage sludges to farmland. This was followed by a field evaluation of various equipment including a tank truck, sludge injector, bulldozer, front-end loader and an all-terrain vehicle to determine:

- (a) the effect of vehicle traffic on natural vegetation,
- (b) the suitability of, and problems associated with various types of equipment for the spreading of sewage sludge on wet fields,
- (c) the effect of type of vehicle on compaction of the soil,
- (d) the effect of using sludge injectors in applying sludge to the land and especially to frozen ground, and
- (e) the suitability of applying sludge by spray irrigation.

### Results and conclusions

- (a) None of the vehicles tested proved ideally suitable and effective in the spreading of sludge on wet soils.
- (b) Sludge spraying was the most effective system for sludge application to farmland in mild and calm conditions and with well-screened sludge.

Summary of Research Report No. 53

Project 73-5-9: LAND APPLICATION OF DIGESTED SLUDGE UNDER ADVERSE CONDITIONS  
- Regional Municipality of Niagara

Land disposal of municipal sewage sludge, without further treatment and under adverse conditions, was considered in this report. Because of its fertilizer and soil conditioning qualities, and its relatively low cost, the digested sewage sludge is usually applied to the land by tank truck.

Problems are associated with this practice of land application during the autumn and spring months. Soils are soft and wet because of rain and the thawing of snow, and conventional sludge hauling vehicles are unable to drive over fields without becoming mired or causing excessive rutting and compaction of the soil. Consequently, sludge storage facilities are required. Storage can be provided in the digesters, but this is limited, and introduces many other problems.

In this study the assumption was made that the fertilizer and soil conditioning values of digested sludge are best utilized by field crops as opposed to incinerating or landfilling.

The objectives of the study were:

1. to determine the suitability of various types of tracked vehicles and low pressure wheeled vehicles for the spreading of sludge on wet fields;
2. to determine the effect of using injectors in applying sludge to the land, especially to frozen ground;
3. to determine the effect on crops of the various means of application;
4. to evaluate the effectiveness of sludge spraying as a means of sludge application to land.

The conclusions reached were rather negative. None of the vehicles or methods investigated proved to be ideally suitable and effective. The bulldozer type vehicle was too slow and heavy, causing excessive damage to the topsoil and turf. The front-end loader was too cumbersome, and also caused excessive field damage. Spreading was too

slow with the all-terrain vehicle, and it also caused field damage. The sludge injector caused the least field damage, but frequently clogged, and was ineffective in hard soil. The tank truck also caused minimal field damage, but became easily mired, in which case it then caused excessive field damage. Sludge spraying was the most effective system in mild and calm conditions and with well-screened sludge.

The opinion is expressed that there is perhaps no single simple solution, and that any choice made for a particular situation at best will be a compromise between effective sludge spreading and minimal difficulties.

## PROJECT SUMMARY

Project Title : Development of an Efficient Sampling Strategy to Characterize Digested Sludges

Project Leader : J.P. Stephenson

Project Number : 74-3-16

Contractor : Fisheries and Environment Canada  
Wastewater Technology Centre

Contract Time : 1974 - 1976

Project Status : Completed

Status of Report: Report is in process of publication in mid 1977.

### Description and summary

A well-founded sampling strategy is essential in the characterization of process streams and process outputs. Without judicious sampling, it may be true that little reliability can be placed in the estimated characteristics of these processes. Good sampling and good records can reduce the effort needed to obtain a maximum amount of information. A thorough baseline survey may make it possible to limit monitoring activities to a level at which high quality can be sustained; this may prevent those responsible for operations from losing sight of the sampling objectives. This report sets out a rational baseline strategy for sampling anaerobically digested sludges.

Previous studies have shown a marked variability in the nutrient and heavy metal constituents of digested sludges within the same water pollution control plant; this variability could not be related to sampling procedures, nor attributed to any cause other than inherent, random heterogeneity. With increased concern for sludge handling, treatment, and disposal, a reliable and efficient sampling strategy is required for sludge characterization. New guidelines for sludge disposal on land, such as those being formulated in Ontario, will require that sludge constituent concentrations be estimated, and that sludge application rates be controlled to meet regulations. Sludge conditioning at plants where sludges are dewatered may also require precise

determination of sludge constituents, especially solids. These factors imply a direct need for efficient sampling strategies.

Data were collected to identify important sources of variation, to determine when sampling would be most productive, and to provide estimates of relative precisions in constituent concentrations. The study was performed at five Ontario water pollution control plants; each plant used the conventional activated sludge process with anaerobic digestion of raw and waste activated sludges. No changes were made in routine operating procedures at these plants, and no attempt was made to control variations. Liquid sludges were sampled both at plants from which sludges were hauled by truck to land disposal sites (batch mode) and at plants where sludges were dewatered (semi-continuous mode). Sampling programs varied from two-week periods to five-month periods. Analyses included solids, nutrients (TKN,  $\text{NH}_4\text{-N}$ , phosphorus), and heavy metals (Fe, Al, Ni, Cu, Zn, Pb, Cd). To estimate the characteristics of long term variations, and to obtain an appropriate sampling frequency, plant records for total solids for two-year periods were examined for two of the plants.

### Results and conclusions

1. The greatest contribution to digested sludge variability occurred within a single operating day for batch and semi-continuous withdrawal modes. Variability between days was masked by within day variability during two or three-week periods. Sample handling and analytical determinations were usually the smallest sources of variation.
2. A sample, composited from the input of discrete tank truck batches, can provide estimates of mean constituent concentrations with relative precisions in the range  $\pm 7$  to  $\pm 55\%$ ; more precision is obtained for liquid phase constituents.
3. Multiple batches of sludge hauled from a plant within the same day must be monitored separately. Sludge withdrawal from anaerobic digesters leads to decreased solids concentrations.
4. Variabilities of liquid sludge constituents sampled at plants which dewatered sludge semi-continuously were approximately one-third the

variabilities observed at plants which disposed by batch truck loads. A composite sample, collected from the feed to a dewatering device, can provide estimates of mean constituent concentrations with relative precisions in the range  $\pm 5$  to  $\pm 15\%$ ; the greater degree of precision is obtained with liquid phase constituents. The semi-continuous pumping from the secondary digester to a dewatering device accounted for a decrease in variability.

5. Total solids concentrations from two different plants' records were characterized by means which did not vary with time during two-year periods. Observations taken at one plant deviated randomly from the mean. Observations at the second plant were not random, but were autocorrelated owing to similar variations in the input to the system.
6. Digested sludge total solids concentrations can be efficiently monitored by using a randomly selected one-day sampling program for every two-week period at plants practising batch or semi-continuous type sludge withdrawal. Implications are that other sludge constituents may also be monitored in this way.
7. Significant changes in constituent concentrations other than total solids occurred during time periods of several months. Correlation of heavy metal concentrations to total solids concentration was an unreliable technique for their prediction during similar periods of time. Heavy metal concentrations were correlated with total solids concentrations over two or three-week time periods.
8. Liquid phase constituents ( $\text{NH}_4\text{-N}$ , TDS) were less variable than solid phase constituents (heavy metals, TKN, TP) at plants which disposed of sludge batchwise or semi-continuously.
9. Short circuiting and dead space existed in two primary digesters, and were considered the result of inefficient mixing. Mixing inefficiency increases the heterogeneity of the end product, and can decrease digestion efficiency.

## PROJECT SUMMARY

Project Title : Investigation of Parasites in Sewage Sludge

Project Leader : H.J. Graham

Project Number : 74-1-41

Contractor : Ontario Ministry of the Environment  
Development and Research Group

Contract Time : 1974 - 1978

Project Status : To be completed in 1978

Status of Reports: No reports yet issued

### Description and summary

The literature review is quite extensive and contains over 100 references to date on the subject of this project. The general consensus thus far is that sewage treatment processes have little effect on the viability of many parasitic ova, especially the more resistant types, and that most parasitic organisms in sewage end up in the sludge.

Ninety-eight samples of raw and digested sludge from six sewage treatment plants have been examined with over half being from a single plant. Most of these samples were analyzed for parasite ova using the same techniques used for faeces samples where the ova are present in relatively large numbers. Using these techniques, 29 raw sludge samples from one sewage treatment plant were analyzed and three Ascaris ova and one Trichuris ova were found. Digestion appeared to concentrate the ova since five Ascaris ova and four Trichuris ova were found in 24 samples of digested sludge from the same plant. In the positive samples the estimated number of eggs present varied from 150-1000/l. These methods are very time consuming and inefficient for sludge since only 10 ml from each sample can be examined in six hours.

To look at a larger portion from each sludge sample in a reasonable length of time a zonal rotor was attached to the centrifuge. The rotor separation method uses the same basic principle as the other methods but is more flexible and a much larger sample can be used. It was found that the rotor could effectively handle from 50 to 200 ml of

5% sludge or several litres of plant effluent. Using sludge samples seeded with parasite ova from dogs and cats, the rotor separation method was less efficient than the previous methods for two types of ova but more efficient for three other types.

Using the rotor in 19 samples of 35 to 200 ml of raw and digested sludge a total of 55 parasite ova were recovered of six different types. The concentrations of the parasites in these samples ranged from 10 to 180 per litre which is much lower and more realistic since ova were usually found in every sample.

One important area still to be examined is the survival of the parasite ova in sludge once it has been applied to farmland. Several methods have now been tested to find parasite ova in soil samples. None so far have been completely successful, although one is fairly efficient for certain types of ova. Work is continuing, using ova from horses and dogs, to find a suitable method for most of the parasitic ova. To find the survival times, fields can be examined that have had sludge applications at various times in the past. Another method to find the survival rate would be to seed a small fenced area of a field with similar ova from domestic animals and examine the soil periodically for many months.

### Results and conclusions

Thus far several types of parasite ova, infective to man and domestic animals, have been found in digested sewage sludge. The literature indicates a long survival of some of these ova. Where repeated sludge applications are applied a build up would be expected. However, the hazard that these parasite ova represent has yet to be determined since there is very little documented evidence of parasitic infection from sewage sludge.

## PROJECT SUMMARY

Project Title : Survey of Ontario Sludge Disposal Practices  
Scientific Liaison Officer: D.B. Cohen  
Project Number : 74-3-19  
Contractor : Michael Antonic  
Fisheries and Environment Canada  
Wastewater Technology Centre  
Contract Time : 1974 - 1976  
Project Status : Completed  
Status of Report : Final Report is compiled and is expected  
to be published early in 1978.

### Description and summary

A survey of 187 mechanical water pollution control (WPC) plants in Ontario serving about 5.6 million people (including 59 plants practising chemical addition for phosphorus removal), was conducted between June and October, 1975. The data gathered by questionnaires and site interviews were analyzed to obtain information concerning wastewater treatment characteristics, sludge production and treatment, with particular emphasis on sludge disposal. Data were analyzed according to WPC plant operational jurisdiction, i.e., Ontario Ministry of the Environment (MOE) run plants, and non-MOE run plants, as well as degree of treatment (primary, secondary) for both standard plants (without chemical addition) and upgraded plants (with chemical addition for phosphorus removal).

### Results and conclusions

Survey response ranged from 100% for sludge incineration and lagooning information to only 6% for data concerning oxygen uptake during aerobic digestion, with 93% for data on flows and population served, 88% for data concerning sludge disposal on farm land, 84% for data concerning sludge disposal quantities, 83% for data on wastewater treatment characteristics, 63% for sludge production data, 54% for sludge treatment data, and 28% for data on sludge quality. Data from

sludge treatment data, and 28% for data on sludge quality. Data from plants responding were reviewed and checked for accuracy before being analyzed.

The WPC plants surveyed received relatively higher per capita flows (145 gal/day), BOD (0.21 lb/day) and SS (0.34 lb/day) loadings, than values commonly used for design purposes. Of the plants surveyed, 45.3% were overloaded hydraulically and 27.0% organically. Numerous operational problems were identified including insufficient pumping capacity and inadequate sludge return capacity. Clarifier solid-liquid separation was often cited as being a major limiting unit process.

The effluent quality objectives of 15 mg/l BOD and SS were routinely exceeded by 38% and 58%, respectively, of standard activated sludge plants. Addition of chemicals for phosphorus removal at primary plants increased mean BOD and SS removals from 43% and 54% to 64% and 79%, respectively. No significant improvements in BOD and SS removal were observed following chemical addition at secondary plants.

The annual average sludge production at the standard primary and secondary plants surveyed was 0.15 and 0.21 lb/capita/day, respectively. The volume of sludge produced per volume of wastewater treated was 0.18% and 0.39% for standard primary and secondary plants, respectively. At primary plants, chemical addition increased sludge production 70% (by volume) and 113% (by weight) and at secondary plants 14% (by volume) and 34% (by weight).

Anaerobic digestion, the most common sludge treatment process in Ontario, was usually effective in reducing sludge organic content, but only 67% of the anaerobic digestion facilities and 42% of aerobic digestion facilities had adequate operation and process control data.

Approximately 66% (156,000 tons dry solids/year) of all sludge production in Ontario (standard and upgraded) is disposed of, compared to 70% (45,000 tons dry solids/year) for chemical wastewater sludges. Sludge disposal on agricultural land accounts for approximately 34% of the total. Sludges from the majority of treatment plants surveyed were found to comply with OMAF tentative guidelines for sewage sludge utilization on agricultural lands. Virtually none of the farmers surveyed were aware of any health hazards or adverse effects on crops or cattle due to sludge disposal on land.

On the basis of information supplied by the farmers surveyed, sludge application to agricultural land at an average rate of 10,650 gal/acre•year (2 tonnes dry solids/acre•year) benefited farmers by approximately \$120/acre in fertilizer savings, crop yield increase and cattle weight gain. This method was also the most economical means of sludge disposal for the WPC plants surveyed.

Average sludge haulage costs were \$1.63/yd<sup>3</sup> of liquid, \$18.20/dry ton sludge cake (18% TS), \$32/dry ton digested primary sludge (8.8% TS), \$52/dry ton digested secondary sludge (4.1% TS) and \$98.9/dry ton undigested sludge (2.8% TS).

#### Recommendations forthcoming from the survey

1. Design criteria concerning BOD and SS loadings, and flow per capita per day should be revised in order to minimize overloading of treatment and digestion facilities.
2. Techniques of sludge application and distribution to farmland should be improved in order to minimize land compaction.
3. Sludge sampling and analysis of sludge nutrients (N, P, K) and heavy metals content should be improved to establish proper application rates.
4. Control of industrial wastewater discharges to municipal sewer lines should be improved to allow larger municipalities to beneficially recycle sludge to farmland.
5. Sludges having high heavy metals concentrations presently being applied to farmland should be thoroughly investigated under field conditions. Their continued application on farmland should be closely controlled.
6. The proper interval required between application of digested sludge to pasture grass and initiation of cattle grazing requires further investigation to minimize the chance of infestation with human tapeworms.
7. In view of the limited time that chemical addition for P removal had been underway during this survey period, this factor should be reassessed in several years, after the majority of WPC plants in Ontario have had sufficient operational experience for a "before" and "after" evaluation.

8. Similar surveys of sludge disposal practices across Canada should be encouraged to gather national inventory data for design and operation of sludge management facilities.

Based on the results of this survey, the per capita wastewater flow, BOD and SS loadings and sludge production values commonly used for design purposes are too low and should be revised. Application of wastewater sludges to Ontario agricultural land is an effective and economical means of ultimate disposal provided sludge quality is adequately monitored and application rates are maintained within the recommended guidelines.

## PROJECT SUMMARY

Project Title : Determination of Existing Levels of PCB's and Heavy Metals at Selected Sludge Disposal Sites in Ontario

Project Leader : D.B. Cohen

Project Number : 76-3-26

Contractor : Fisheries and Environment Canada  
Wastewater Technology Centre

Contract Time : 1976 - 1977

Project Status : To be completed in 1977

Status of Report: Report is expected in late 1977 and will be published in 1978

### Description and summary

In order to assess the present status and magnitude of PCB and heavy metals concentrations in soils and vegetation at sludge application sites to agricultural land in Ontario, disposal sites were selected based on the following criteria:

- (i) sludges previously disposed of at these sites should have had a PCB concentration higher than 5 mg/g dry weight,
- (ii) or the disposal site should have been in continuous operation for more than five years,
- (iii) or the liquid sludges being disposed of should have a metal flux (Zn + Cu + Ni + Pb + Cd + Cr) value of more than 100 mg/l.

The major objective of this study was to assess the levels of PCB's and heavy metals in soils and crops from selected sludge disposal sites compared to adjacent non-sludged sites in Ontario.

Ten sludged sites were selected which included crops of corn, oats and wheat. Source sludges were collected, sampled and analyzed. Surface soil samples (0-15 cm) were obtained from both sludged soil sites and adjacent control fields. Oat samples were taken (whole plant) at the boot stage of plant development. Wheat samples were relatively mature plants; however, only the stems and leaves were used for analysis.

Corn sampling consisted of first, third and fifth leaf from the top of the plant. The corn crop was in early tassel stage of plant development when sampled.

All sludge, soil and plant samples were analyzed for nickel, copper, lead, zinc, manganese, cobalt, chromium, molybdenum, arsenic, mercury, cadmium, selenium and PCB's.

#### Results and conclusions

Initial results indicate that the PCB concentration is generally not increased in crops when grown on sludge amended soil, in fact decreases occurred in seven of nine comparisons. Although many of the heavy metals exceeded the Ontario Ministry of Agriculture and Food maximum recommended content in soils, concentrations in plant tissue generally were not significantly greater than concentrations of these metals in plant tissue from control sites. Only one site had a potentially toxic (to grazing cattle) concentration of molybdenum in corn stover (24  $\mu\text{g/g}$ ). Complete results had not been summarized by the summer of 1977 making it impossible to present final conclusions.

## TECHNOLOGY TRANSFER PRESENTATIONS

### SLUDGE HANDLING AND DISPOSAL SEMINAR - Toronto, Ontario, September 18-19, 1974. Conference Proceedings No. 2

A significant concern of this seminar was the handling and disposal of sludges produced from the chemical treatment of sewage for phosphorus removal. Recently, questions have arisen concerning the potential environmental problems associated with land method of disposal and the introduction of chemical sludges from phosphorus removal facilities has further complicated these questions. Studies were needed to fully understand and determine the nitrogen balance, and movement and fate of nitrogen compounds in soils, plants and water. The level of heavy metals in sludges is also of concern because of potential problems associated with build-up in soil, uptake by plants, effect on plant growth, runoff, pollution of groundwater and leaching after long-term build-up in soil. In addition, very little is known about the pathogenic aspects of sewage sludge disposal on land.

When the agenda was arranged for this Sludge Handling and Disposal Seminar, an attempt was made to divide the presentations into two areas, namely handling and disposal, with concurrent sessions on the second day. This division was realistic in view of the fact that approximately one-half the sewage sludge from Ontario Water Pollution Control Plants is added to land and one-half is disposed by other means.

The sludge handling topics discussed at the seminar covered such subjects as: dewatering, filtration, centrifugation, incineration, metal removal or reclamation, trucking and pumping. Results of research projects funded under the Canada-Ontario Agreement on both sludge handling and disposal were discussed by approximately thirty authors and researchers. The audience was broad in interest scope, consisting of sewage plant operators, administrators, sanitary engineers, pollution oriented researchers and consultants. Regulatory and agricultural personnel from the federal and provincial governments, as well as university staff, also attended the seminar.

The papers presented and contained in Conference Proceedings No. 2 should serve as a useful reference in the area of sewage sludge handling and disposal.

Papers presented at the 1974 Sludge Handling and Disposal Seminar and published in Conference Proceedings No. 2

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Overview of Canadian Sludge Handling and Land Disposal Practices and Research

S.A. Black, Ontario Ministry of the Environment,  
N.W. Schmidtke, Fisheries and Environment Canada.

Sludge Handling and Disposal Practices in England

J. Webber, Ministry of Agriculture, Fisheries and Food, England.

Use of Sewage Sludge in Agriculture with Adequate Environmental Safeguards  
W.E. Larson, R.H. Susag, R.E. Larson, United States Department of Agriculture.

Aerobic and Anaerobic Sludge Digestion

B.I. Boyko, Ontario Ministry of the Environment.

Biochemical Characteristics of Digested Chemical Sewage Sludges

V.K. Chawla, J.P. Stephenson and D. Liu, Fisheries and Environment Canada

Virological Investigations on Sludges from Selected Ontario Sewage Plants

T.P. Subrahmanyam, Ontario Ministry of Health.

Regulatory Aspects of Sludge Utilization on Land

G.M. Wood, Ontario Ministry of the Environment.

Agricultural Use of Sludge

L.R. Webber and B.C. Hilliard, University of Guelph.

Land Disposal of Sewage Sludge

T.E. Bates, E.G. Beauchamp, J.W. Ketcheson, R. Protz, J.R. Moyer,  
A. Haq, W. Curnoe, R.A. Johnston, University of Guelph.

Effects of Sewage Sludge on Crop Growth and Nutrient and Metal Uptake

T.E. Bates, J.R. Moyer and A. Haq, University of Guelph.

Nitrogen Transformation and Uptake

E.G. Beauchamp and J. Moyer, University of Guelph.

Runoff and Erosion Losses

W.E. Curnoe, University of Guelph.

Some Microbiological Aspects of the Land Disposal of Sludge

R.A. Johnston, University of Guelph.

Cation Distribution in Soils as Related to Sewage Sludge Disposal on Land  
R. Protz, University of Guelph.

Disposal of Chemical Sewage Sludges on Land and Their Effects on Plants,  
Leachate and Soil Systems

V.K. Chawla, D.N. Bryant and D. Liu, Fisheries and Environment  
Canada.

Analysis of Heavy Metals in Sewage Sludge and Liquids Associated With Sludges  
Jon C. Van Loon, University of Toronto.

Extractable Metals in Mixtures of Soil and Sewage Sludge

M.D. Webber and J.D. Gaynor, Agriculture Canada.

Chemical Tests for Plant Available Metals in Soils

T.E. Bates and A. Haq, University of Guelph.

Design Information on Dewatering Properties of Wastewater Sludges

J.B. Farrell, United States Environmental Protection Agency.

Effects of Control Variables and Sludge Characteristics on the Performance  
of Dewatering and Thickening Devices

H. Campbell, and B.P. LeClair, Fisheries and Environment Canada.

The Use of Physicochemical Sludge Characteristics and Bench Dewatering  
Tests in Predicting the Efficiency of Thickening and Dewatering Processes

R. Stickney and B.P. LeClair, Fisheries and Environment Canada

Centrifuges Types and Applications

Frederick W. Keith, Jr., Pennwalt Corporation.

Sludge Dewatering Using the Kruger Centrifuge

L.P. Roe, The East Asiatic Company (Canada) Ltd.

Vacuum Dewatering of Sewage Sludge

Geoffrey D. Kemp, Komline-Sanderson Limited.

Aspects of Incinerating Chemical Sludges

E.E. Shannon, D. Plummer and P.J.A. Fowlie, Fisheries and Environment  
Canada.

Removal of Phosphates and Metals from Sewage Sludges

D.S. Scott and H. Horlings, University of Waterloo.

Sludge Handling and Disposal Practices in the Regional Municipality  
of Niagara

E.R. Simonen, Regional Municipality of Niagara

Sludge Handling and Disposal Practices in Metropolitan Toronto

W.A. Salib, Toronto, Ontario.

LAND DISPOSAL OF SEWAGE SLUDGE WORKSHOP - Guelph, Ontario, June 10, 1975.

The Land Disposal of Sludge Subcommittee held a Workshop at the University of Guelph, Guelph, Ontario on June 10, 1975 on the subject of Land Disposal of Sewage Sludge. At this workshop the contractors, project leaders and scientific liaison officers discussed their mutual interests relative to the various projects of the Subcommittee. There was no official report issued on the proceedings of this Workshop.

SLUDGE HANDLING AND DISPOSAL SEMINAR - Calgary, Alberta, February 16-18, 1977.

Several project leaders and Land Disposal of Sludge Subcommittee members assisted by participation in the Sludge Handling and Disposal Seminar held in Calgary, Alberta on February 16 - 18, 1977, sponsored by the Province of Alberta, Department of Environment, the Western Canada Water and Sewage Conference and Environmental Protection Service, Fisheries and Environment Canada.

SEWAGE SLUDGE UTILIZATION AND DISPOSAL SEMINAR - Toronto, Ontario, February 20 & 21, 1978.

The program for this Seminar is as follows and this subject report was compiled for distribution at this Seminar.

Papers presented at the Sewage Sludge Utilization and Disposal Seminar  
February 20 and 21, 1978

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Practices and Trends in Sewage Sludge Utilization and Disposal  
S.A. Black, Ministry of the Environment.

Sewage Sludge Sampling  
J.P. Stephenson, Fisheries and Environment Canada.

Viruses and Parasites in Sewage Sludge  
A.H. Vajdic, Ministry of the Environment.

Sources of Heavy Metals in Sewage Sludge  
J.R. Hawley, Ministry of the Environment.

Land Disposal of Sewage Sludge  
T.E. Bates, University of Guelph.

Lysimeters and Site Monitoring Investigations of Sewage Sludge  
D.B. Cohen, Fisheries and Environment Canada.

Guidelines for Sewage Sludge Utilization and Disposal  
P. DeAngelis, Ministry of the Environment.

Municipal Impact of Sewage Sludge Utilization and Disposal  
G.T. Thompson, Kitchener, Ontario.

Conditioning and Dewatering of Sewage Sludge  
N.W. Schmidtke, Fisheries and Environment Canada.

Sludge Dewatering Design Manual  
H.W. Campbell, Fisheries and Environment Canada.

Sewage Sludge Incineration  
P. Da Silva, Gore and Storrie Ltd., Toronto, Ontario.

Composting of Sewage Sludge  
Windsor, Ontario.

Cost Estimation Techniques for Sewage Sludge Utilization and Disposal  
D.R. Woods, McMaster University, Hamilton, Ontario.

Approval Processes for Sewage Sludge Utilization and Disposal  
J.R. McMurray, Ministry of the Environment.

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